Energy efficiency, productivity and exporting: firm-level evidence in Latin America

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Research Highlights

- We explore the relationship between energy efficiency, productivity and exporting for LAC firms
- Firm-level data come from the national representative World Bank Enterprise Survey
- We find significant but heterogeneous results by firm size and industrial sector
- Outcomes are robust to different measures of energy efficiency
- This work opens the ground to a rethinking of the priorities of energy saving policies

*Abstract

Energy efficiency, productivity and exporting: firm-level evidence in Latin America

P. Montalbano[1]; S. Nenci[2]

Abstract

This work explores the relationship between energy efficiency, productivity and exporting for a sample of firms located in thirty Latin American and Caribbean (LAC) countries . This relationship has not been studied in depth although it is important and relevant to policymaking. We apply a standard constant returns to scale Cobb-Douglas production function with labor, capital, and knowledge expanded to exports and energy efficiency. We also investigate the relationship between energy efficiency and exporting and take heterogeneity by firms and industries into account. Firm-level data come from the national representative World Bank Enterprise Survey (WBES). Our empirical analysis finds heterogeneous results by firm size and industrial sector both in the relationship between energy efficiency and productivity and between energy efficiency and exporting. These outcomes are robust to different measures of energy efficiency and controlling for heterogeneity among countries and provinces. By providing for the first time an extensive investigation of energy intensity and firm performance for such a large sample of LAC countries, this work contributes to the lively debate on LAC energy efficiency and weak productivity. By adopting a broader productivity and international trade perspective, it opens the ground to a rethinking of the priorities of energy saving policies and their environmental impacts.

Keywords: Energy intensity; Energy efficiency; Firm productivity; Exports; Latin America.

JEL classification: D24, L20, O54, Q40.

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1. Introduction

Sustainable development goals (SDGs) call for actions that envisage a pro-active role of the various agents (national governments, economic actors, individuals) in the field of energy and climate. Firms are fully involved in this framework by committing themselves to adopting responsible environmental actions such as increasing investments for innovative and inclusive low-carbon products, reducing the carbon footprint of their production processes, setting emissions reductions targets and improving their energy efficiency.[1] Although much of the growth in energy consumption is expected to occur in the developing world, the adoption of respectful environmental conduct and the enforcement of environmental regulations may be weaker in developing countries, thus relaxing the pressure for corporate environmental commitments. A thorough understanding of these phenomena is severely constrained by a chronic scarcity of data.

This work explores the relationship between energy use, productivity and international trade for a sample of firms located in the Latin America and Caribbean (LAC) region. This relationship, although important and relevant to policymaking, has not been studied in depth. Moreover, environmental impact has been extensively analyzed using data at the level of countries, states, and provinces, but relative few firm-level analyses have been performed (Roy and Yasar, 2015). There are even fewer firm level analyses of the interaction between energy use and trade. Furthermore, little is known about all this with reference to the LAC region.[2] This is a very important case since, on the one hand, the LAC region is one of the major regions in the world that over the past 20 years has experienced rapid increases in trade and energy consumption (Sadorsky, 2012). On the other hand, recent empirical research shows that despite years of rising factor accumulation, slow productivity growth and weak internationalization is at the root of LAC's weak overall performance (Stein *et al.*, 2014; Grazzi and Pietrobelli, 2016; Montalbano *et al.*, 2017). Despite the

[1]See Goal 7 in the SDGs which includes the following target: double the global rate of improvement in energy efficiency. For additional details, see: www.un.org/sustainabledevelopment.

[2]Narayan and Smyth (2009) and Sadorsky (2011) have investigated the relationship between trade and energy consumption for Middle Eastern countries. Lean and Smyth (2010a) and Lean and Smyth (2010b) have investigated the same relationship in Malaysia.

endowment of energy resources, including hydrocarbons, hydroelectricity and biofuels, and the progress that some LAC countries have recently made in terms of using renewable energy sources, most of these economies still need to address key economic, social and environmental challenges in the energy sector. Installed power capacity needs to be doubled to meet a growing demand for electricity (over 34 million people still lack access to electricity); the grid infrastructure is outdated and requires significant modernization and expansion; many Latin American economies still depend on fossil fuels for their power generation; climate change is having a significant impact on regional economy, ecosystems, and human well-being (Majano, 2014).

Thanks to the availability of firm-level data for thirty LAC countries from the national representative World bank Enterprise Survey (WBES) dataset developed in collaboration with the Inter-American Development Bank (IBD) and extended also to firms located in the Caribbean countries, we provide a first comprehensive empirical analysis of the relationship between energy use on both firms' productivity and their exporting status for the main manufacturing industries in the LAC region, controlling for industry and firm heterogeneity. Since energy efficiency is widely recognized as the most cost-effective approach to addressing energy-related issues and increases in competitiveness (International Energy Agency, 2014), we will focus our empirical analysis on this key issue. Unlike previous works, we compute energy efficiency for each firm in the dataset, by computing the inverse of three different measures of energy intensity (annual total energy costs, fuel and electricity, to the total value of annual sales; annual total energy costs to annual added value; share of total energy costs to the total annual cost of variable inputs). Since we acknowledge that energy intensity changes by industrial structure (for instance, more energy dependent industries tend to be relatively more energy intensive than other industries) and/or can be induced by changes in energy input mix (Proskuryakova and Kovalev, 2015), our estimates account for heterogeneity in structural energy intensity among firms and industries (Duro *et al.*, 2010; Mulder and de Groot, 2012; Grossi and Mussini, 2017).

To test whether energy efficiency affects firm performance, we apply a standard constant returns to scale Cobb-Douglas production function with labor, capital, and knowledge expanded to export performance. Since panel data are only available for an handful of firms, to increase the consistency of our estimates, we have pooled all sampled data to take advantage of the total number of observations available for each country and industry included in the dataset. The use of dummies for countries, industries and provinces clean up our estimated coefficients from common trends at the level of countries, industries and provinces. We also look explicitly at the relationship between energy efficiency and exporting by investigating the correlates between the two variables in the spirit of the new approach to international trade based on firm heterogeneity (Melitz and Redding, 2014).

Our empirical analysis finds heterogeneous results by firm size and industrial sector both in the relationship between energy efficiency and productivity and between energy efficiency and exporting. These outcomes are robust to different measures of energy efficiency and controlling for heterogeneity among countries and provinces. Given the difficulty in determining a causal linkage, the empirical validation of whether cross-industries and cross-firms differences in energy efficiency are correlated with differences in productivity is very relevant. It provides useful unconventional policy insights both for local firms and governments. For instance, it demonstrates that non-energy benefit in terms of productivity gains should be considered in the overall assessment of the policies on energy efficiency. Conversely, the fact that energy efficiency does not correlate, on average, with the export status of the investigated firms fosters complementarity between environmental regulations and trade liberalization policies. The final suggestion is in line with previous literature (Boyd and Pang, 2000), that is energy saving policy priorities need to be revised adopting a broader productivity and international trade perspective.

The rest of the paper is organized as follows: Section 2 briefly describes the two main strands of the literature that are key for our work; Section 3 introduces the dataset, provides the indicators of energy intensity and shows some stylized facts on firm characteristics in LAC countries; Section 4 presents the empirical methodology and reports the outcomes of the empirical analysis; Section 5 concludes and provides policy implications.

2. Review of the literature

Over the last decade, the literature on the relationship between environment and a firm's economic performance has increased considerably. In this paper we refer specifically to two strands of this literature: the one that looks at the link between environment and productivity and the one that analyzes the link between environment and international trade.

The debate over the impact of environment on productivity is directly ascribable to the so-called "Porter hypothesis". The Porter hypothesis claims that the right kind of stringent environmental regulation could induce firm innovation, increase efficiency, and ultimately improve productivity (Porter and Van der Linde, 1995). There is an extensive empirical literature related to the connection between competitiveness and environmental regulations. Some studies corroborate the "Porter hypothesis" (Dowell *et al.*, 2000; Harrington *et al.*, 2000; Mohr, 2002; Hamamoto, 2006), whereas others have found weak or no Porter effects (Gray and Shadbegian, 1993; Walley and Whitehead, 1994; Boyd and McClelland, 1999; Boyd *et al.*, 2002;

Brännlund and Lundgren, 2010). Wagner (2003), Brännlund *et al.* (2009), Molina-Azorín *et al.* (2009), Heras-Saizarbitoria *et al.* (2011) all provide literature reviews on the Porter hypothesis. The general findings are a lack of empirical support for the Porter hypothesis which could be affirmed under very special assumptions and conditions. Several studies have referred specifically to industrial productivity benefits associated with energy efficiency (see, among others, (Boyd and Pang, 2000; Worrell *et al.*, 2003; Eifert *et al.*, 2005)). As argued by Zeng *et al.* (2010), the main difficulty in drawing clear conclusions from previous studies probably also lies in the fact that scholars use different definitions and measures of environmental performance.

With regard to the second aspect, a growing literature has examined the relationship between environment and international trade. The intuition here is that improved foreign market access is associated with innovation which is generally energy saving (Bustos, 2011; Lileeva and Trefler, 2010; Roy and Yasar, 2015) or, alternatively, that exporting comes with management practice as in the "learning by supplying" paradigm (Alcacer and Oxley, 2014) which in turn may encourage a reduction in energy intensity via energy efficiency (Bloom *et al.*, 2010). Another strand of the same literature highlights that a decrease in energy consumption could also hamper international competitiveness and negatively affect the ability to produce goods destined for exports (Sadorsky, 2012). In a more general context, some empirical works have tested the trade-environment relationship (see, among others, (Tobey, 1990; Jaffe *et al.*, 1995; Antweiler *et al.*, 2001; Cole and Elliott, 2003; Ederington and Minier, 2003)), but the empirical findings are mixed (Brunnermeier and Levinson, 2004). Moreover, these empirical studies are still rather limited at firm level. Among the few firm level analyses, Galdeano-Gómez (2010) shows that environmental performance has a positive relationship with exports of Spanish food firms. Cole *et al.* (2006) highlight a positive influence of exports on environmental performance for firms in Japan. No matter whether lower energy intensity practices are positively or negatively associated with exporting, the presence or absence of a significant empirical correlation between these two variables would have significant implications for policymaking.

3. WBES data and indicators of energy intensity in the LAC region

WBES provides a national representative stratified random sample of firms. It uses three levels of stratification: province, sector, and firm size. The industry classification is based on the ISIC Rev. 3.1. An additional advantage of WBES is that the survey questions are the same across all countries thus allowing cross-country comparison.[3] In this work we use a subset of the WBES database that specifically focuses on

[3] The national representative World Bank Enterprise Survey (WBES) has centralized most of the firm-level surveys conducted since the 1990's by different units within the World Bank. WBES data is available for over 131,000 firms in 139 countries.

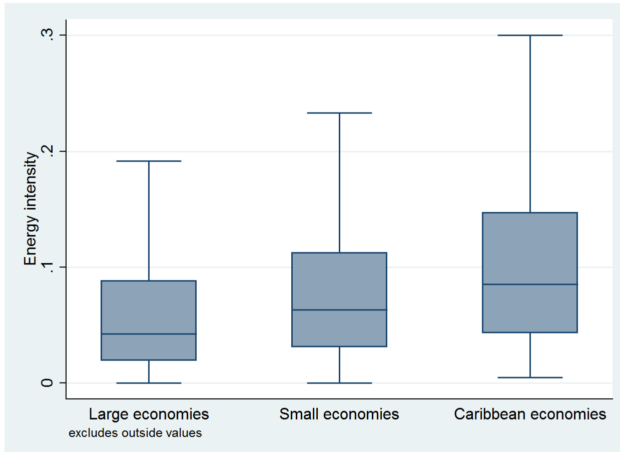
LAC countries, developed by the World Bank in collaboration with the Inter-American Development Bank. It provides data on total sales, value added, exports and annual costs of energy inputs (fuel and electricity) for a sample of 10,441 firms located in 30 Latin American and Caribbean Countries. Two rounds of the same survey were conducted in 2006 and 2010 (2009 for Brazil) collecting data for the last fiscal year. Data for Caribbean countries are only available for the 2010 round. Table A.1 in Appendix A provides information on the LAC sample of firms we analyze by country and survey year (number of total firms, number of exporting firms, and average annual values of energy intensity by firm). Of the Latin American countries above average energy intensities are shown by Panama and Honduras in 2006, Guyana and Mexico in 2010 and El Salvador, Guatemala, and Nicaragua in 2006 and 2010.

The main contribution of our work is to provide firm-level measures of energy intensity. To this end, we take advantage of the availability in WBES of firm-level data on the total expenditure of fuel and electricity for the previous fiscal year to build up indicators of energy intensity for each firm in the sample. We provide three different measures of energy intensity: 1) the first measure is computed as the ratio of the annual energy costs (fuel and electricity) to the value of total annual sales; 2) the second measure is computed as the ratio of annual energy costs (fuel and electricity) to annual value added (the annual value added is computed for each firm by subtracting the total annual costs of inputs - raw materials, intermediate goods, and energy costs - from the total annual sales); 3) the third measure is the cost share, namely the ratio of the annual energy costs (fuel and electricity) to the total annual cost of each firm's variable inputs in last fiscal year. The total cost of the variable inputs is obtained as the sum of fuel and electricity, total labor costs and costs of raw materials and intermediate goods used in production. This third measure does not make use of sales for its computation thus avoiding concerns over endogeneity with our measure of productivity. All the monetary values used in computations are converted into 2009 US dollars.

Fig. 1 summarizes the actual distribution of the firms' energy intensities, measured as the share of total energy costs, fuel and energy, to firms' total variable costs (cost share energy measure), by the main LAC country groups. It highlights evidence of strong heterogeneity across groups of countries with firms in Caribbean countries showing, on average, higher and more dispersed levels of energy intensity.

Survey data are collected through face-to-face interviews with firm managers and owners regarding the business environment in their countries and the productivity of their firms, including questions relating to infrastructure, sales and supplies, competition, crime, finance, business development services, business-government relations, labor, and firm performance. Standardized survey instruments and a uniform sampling methodology are used to minimize measurement error and yield data that are comparable across the world's economies. Specifically, the sampling methodology generates large enough samples that are representative of the whole non-agricultural private economy. For additional details on WBES, see http://www.enterprisesurveys.org.

Figure 1: Box Plots of the distribution of energy intensities across LAC firms by main country groups

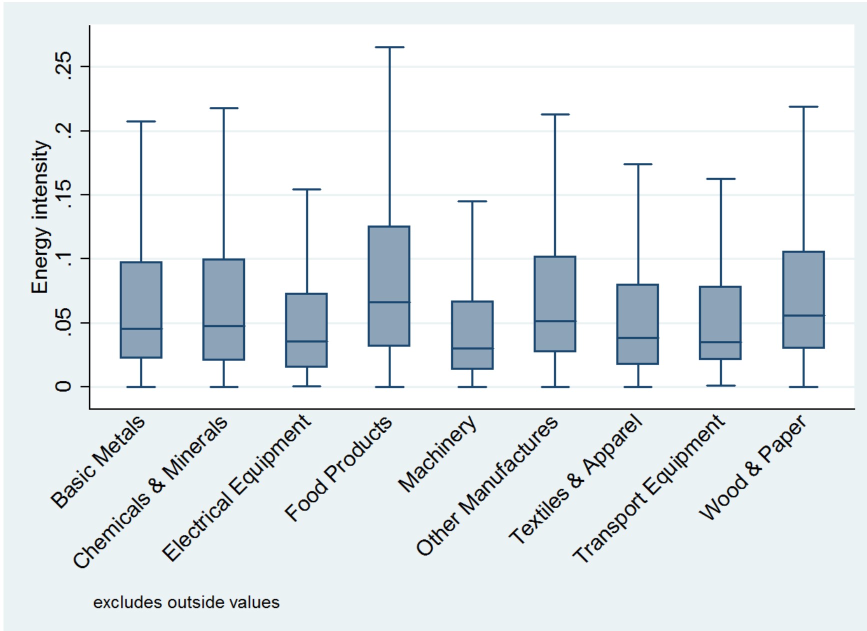


Energy intensities are computed for each firm as the ratio of annual total energy costs, fuel and electricity, to total annual cost of variable inputs. Source: Authors' elaborations from WBES

Fig. 2 shows the box plots of the same measure of energy intensity by the main manufacturing industries[4]. It confirms the presence of strong heterogeneity in the distribution of firms' energy intensity across industries (the average levels by industry for all the computed measures of energy intensity are reported in Table A.2). It is noteworthy that "food products" is the industry characterized by the most energy intensity in the LAC region (it shows the highest median value across firms). Furthermore, it shows the highest variability of values around the median. This heterogeneity is higher specifically for values towards the upper quartile, and especially higher towards the upper tail. Conversely, "electrical equipment", "machinery" and "transport equipment" host the highest number of energy saving firms and much less heterogeneity. This is consistent with the hypothesis of the relative efficiency of the industrial sectors characterized by relatively higher energy consumption, probably due to higher technological standards.

[4]Note that the top two sectors in energy intensity and use (coke, refined petroleum and nuclear fuel and electricity; gas and water supply) do not show up in the reported manufacturing statistics.

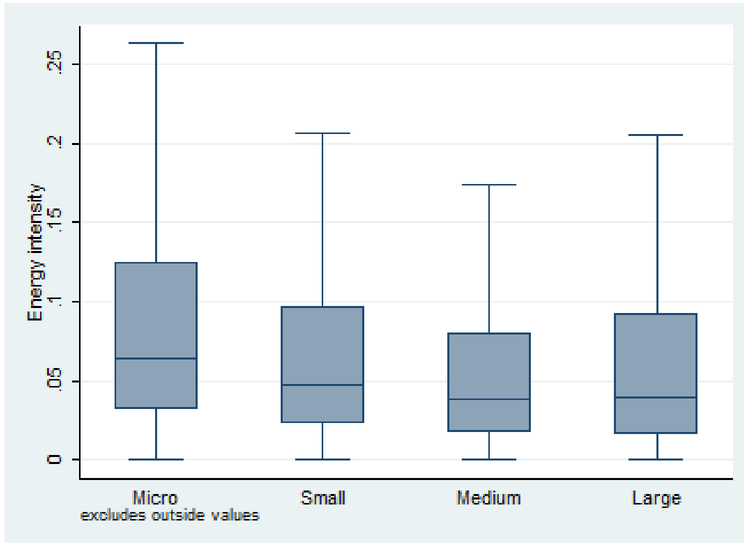
Figure 2: Box Plots of the distribution of energy intensities across LAC firms by main manufacturing industries



Energy intensities are computed for each firm as the ratio of annual total energy costs, fuel and electricity, to total annual cost of variable inputs. Source: Authors' elaborations from WBES

Lastly, Fig. 3 presents the same information by disentangling four firm categories (micro, small, medium and large) on the basis of the number of total permanent full-time workers employed at the end of the previous fiscal year. As is largely expected, micro firms (with less than 10 permanent workers) show, on average, higher energy intensity than the other firms in the sample and also present the highest degree of heterogeneity, especially towards the upper tail. It is noteworthy that firms in the medium category (with a number of permanent workers in the interval: 50-250) show levels of energy intensity which are comparable with those of the larger firms (more than 250 permanent workers) and a sensible lower degree of heterogeneity. Although it is true that larger firms are much bigger than medium ones (six times larger on average: about 620 full time employees on average for large firms out of 116 on average for the medium ones), the former are also much more heterogeneous (the size of larger firms ranges from 252 employees up to 4,500). Table A.3 in Appendix provides the average values for all the measures of energy intensity by firm. It confirms that firms classified as medium register the lowest average energy intensity in two measures out of three.

Figure 3: Box Plots of the distribution of energy intensities across LAC firms by firm size



Energy intensities are computed for each firm as the ratio of annual total energy costs, fuel and electricity, to total annual cost of variable inputs. Source: Authors' elaborations from WBES

To investigate the relationship between energy efficiency and productivity in our empirical analysis, we use the traditional measure of the inverse of the above energy intensity measures. We acknowledge that there is a heated discussion about the best measure of energy efficiency (Patterson, 1996; Freeman *et al.*, 1997; Proskuryakova and Kovalev, 2015) and that data on energy intensity does not automatically provide information on energy efficiency. However, we consider this to be a workable way to provide useful insights into the correlates between energy consumption and productivity at the firm level by taking advantage of the availability of detailed firm-level data. Our hypothesis is that higher values of energy efficiency (computed as the inverse of our indicators of energy intensity) are positively correlated with higher firm productivity and eventually exports. As a measure of firm-level productivity, here we use labor productivity. We acknowledge this is not the only measure of productivity, but the available LAC WBES dataset is not suited to calculating other measures (e.g., total factor productivity) using standard methodologies. In order to clean our dataset for potential outliers and keep consistency with the hypothesis of normal distribution in the subsequent empirical analysis, we applied the minimum covariance determinant (MCD) estimator which has become standard in robust statistics to identify outliers and is particularly well suited for multivariate outlier identification.[5] We also omitted firms with fewer than five employees.

[5]The basic idea of MCD is to identify the subsample containing 50% of the observations associated with the smallest generalized variance. For additional information, see Verardi *et al.* (2010).

4. Empirical analysis

The aim of our empirical exercise is to investigate whether there is a relationship between energy intensity and firm performance in terms of labor productivity and exporting in our sample of LAC firms. To this end, we expand the following version of the standard constant returns to scale Cobb-Douglas production function with labor, capital, and knowledge to export performance and energy intensity[6]:

$$\theta_i = \gamma + \gamma_1 k_i + \gamma_2 h_i + \gamma_3 exp_i + \gamma_4 z_i + \gamma_5 ei_i + \eta_c + \eta_p + \eta_j + \epsilon_i. \tag{1}$$

where i denotes firms; θ_i is firm labor productivity, k_i is firm "capital intensity", h_i is "human capital" (proxied by the percentage of full time workers with bachelor degree on total workers); exp_i is a dummy for exporting firms; z_i is a proxy for "technological innovation"; ei_i is our variable of interest, proxied by our firm-level measures of energy efficiency in terms of fuels and electricity; η_c, η_p and η_j are dummies for country, sub-national region (provinces) and industry, respectively, to control for bias due to unobserved factors; ϵ_i is the error term that includes all potentially time-varying and time-invariant unobservables (including the price of inputs). All variables are in logs except for dummies and percentages. z_i is a sensible control because of the likely association between energy efficiency, innovation and productivity (Hall and Jones, 1999; Rouvinen, 2002; Guloglu and Tekin, 2012; Crespi *et al.*, 2016). Indeed, in many Latin American economies, firms' innovations mainly consist of incremental changes with little or no impact on international markets and are mostly based on imitation and technology transfer, such as the acquisition of machinery and equipment and disembodied technology (Pagés, 2010). As a result, the empirical evidence on the impact of innovation on labor productivity in the case of LAC firms has been quite inconclusive (Pérez *et al.*, 2005; Chudnovsky *et al.*, 2006; Benavente, 2006; Raffo *et al.*, 2008; Benavente and Bravo, 2009). A possible explanation for this heterogeneity could be the lack of homogeneous and comparable data across the different LAC countries (Crespi *et al.*, 2016). In this respect, WBES data provides a great opportunity to benefit from comparable data since the survey questions are the same across countries. However, it shares caveats common to all studies that use innovation survey data. Since patent information is almost irrelevant in developing countries (where only a very small set of firms are involved in pushing the technological frontier), making use of self-reported innovation variables is much noisier and subjective (they are based on firms' self-

[6]Since we apply the same production function for all LAC countries and sectors and there is no one-size-fits-all solution, we rely here on the standard Cobb-Douglas restrictions implied by economic theory. This choice is standard in cross-country empirical applications on developing countries (see, among others, (Tybout, 2000; Aiyar and Dalgaard, 2009)) including more recent investigations using the same dataset (see, among others, Crespi *et al.* (2016)).

assessment about their product/process innovations, which is debatable). To this end, following Farole and Winkler (2014), in all our empirical analyses we avoid using self-reported innovation variables and control for the role of "technological innovation" by using a dummy which is equal to one if firms use technology licensed from a foreign owned company (excluded office software), own internationally recognized quality certification (e.g., ISO), and use own website and/or technological communication technologies. We are aware that the original knowledge production models relate knowledge production to R&D (or innovation investment). In the Appendix we therefore provide new estimates in which we have substituted the dummy for "technological innovation" with the amount of money firms declared they had spent on R&D activities in the previous fiscal year. Unfortunately, declarations regarding R&D expenses are only available for a small number of firms.

Note that when carrying out our empirical analysis, we face an appreciable reduction in the number of available firm level observations compared with the total sample of available firms because of the random absence of data for some of the key variables in our production function specification. This constraint is relatively less stringent in the case of the probit estimates on exporter status.

Table 1 reports the estimates of the production function depicted in Eq.1 by pooling our firm-level LAC data and controlling for country, province and industry. As expected, positive and statistically significant coefficients are estimated for the relationship between labor productivity, capital intensity, human capital, technological innovation and firm size, which are all consistent with the theory. Table A.4 in the Appendix reports the same specification by substituting R&D expenses for the dummy for "technological innovation". Whereas the outcomes are of course different in detail from those in Table 1, the parameters for R&D are still significantly positively associated with firms' productivity, with the exception of the category of micro firms (which is actually reasonable) and more importantly, the relationship between energy efficiency and labor productivity does not change significantly. Also consistent with the theory is the evidence of a strong correlation between firm productivity and the status of being a direct exporter. International trade literature provides two main explanations when analyzing export productivity premia: "self-selection" and "learning by exporting". Self-selection means that only the more productive firms can afford the extra costs of exporting (Melitz, 2003). Learning by exporting means that exporters are exposed to knowledge flows and spillover, technology transfers, technical assistance and to more intense competition in international markets which lead to significant improvements in performance (Bernard *et al.*, 2007).

With regard to the key parameters in our analysis, i.e., those attached to our measures of energy intensity, we find, on average, no significant correlation between firm-level energy intensity and firm productivity.

However, when we take into account firm heterogeneity by carrying out separate regressions by firm size (distinguishing micro, small, medium, and large firms), the empirical evidence that firms using lower energy intensity show, on average and *ceteris paribus*, higher productivity than firms with higher energy intensity is apparent in all cases, with the only exception being small firms. These outcomes are confirmed by using different measures of energy intensity, with the latter measure (in terms of the costs of variable inputs) declining in significance in the case of medium and especially large firms.

These outcomes appear to be consistent with the argument of the so-called "Porter Hypothesis". A search for energy efficiency leads to an improvement in productivity and competitive advantage. This entails shortcomings for management and policymaking which are consistent with the view of Porter and Van der Linde (1995) that environmental regulations (such as those consistent with the targets of the SDGs) could be mutual beneficial both for collective and individual (firm-level) actions.

Table 2 reports the same estimates by manufacturing industries. Due to space constraints, we only include in the table the estimates with the cost share measure of energy intensity (which looks more conservative than the others). The estimates with the other measures are always consistent and available in the supplementary material. Consistently with the general case, these estimates confirm in most cases the positive and significant relationship between labor productivity and the set of regressors suggested by the theory, including firm size and the exporter status variable (Eq. 1). More heterogeneous results are those related to energy efficiency. In this case, we can confirm a positive and significant relationship between firm productivity and a energy efficiency for "Textiles and Apparel", "Chemicals and Mining", "Basic Metals", and "'Other Manufacturing"', whereas this relationship turns out to be insignificant for "Wood and Paper", "Food Product" and "Machinery".

A natural extension of the analysis is to look at the relationship between energy intensity and exporting. As already underlined, this relationship is an important yet understudied area of research. While, in fact, the debate on the direction of causality between firm efficiency and exporting is endless and there is no clear-cut evidence in favor of one of the possible interpretations,[7] there is much less evidence in the literature as to whether a reduction in energy intensity correlates with an increase in exports. Furthermore, in this case, we cannot have a priori judgments about the sign of the relationship. On the one hand, a positive correlation is consistent with at least two main strands of the literature. First, according to international trade theory, exporting should be positively correlated with innovation which is generally energy saving. Second, according

[7] For a survey of the empirical evidence of firm level export productivity premia, see Greenaway and Kneller (2007) and Wagner (2007).

Table 1: POLS estimates of labor productivity with different measures of energy efficiency by firm

Dependent Variable:	1/[annual energy expenditure/ total annual sales]					1/[annual energy expenditure/ total annual value added]					1/[annual energy expenditure/ total annual cost of variable inputs]				
(ln) Labor Productivity	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*
	All Firms	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*
(ln) K intensity	0.245***	0.177***	0.189***	0.301***	0.281***	0.246***	0.181***	0.188***	0.302***	0.282***	0.245***	0.176***	0.188***	0.302***	0.271***
	(0.0160)	(0.0393)	(0.0281)	(0.0230)	(0.0345)	(0.0161)	(0.0404)	(0.0282)	(0.0232)	(0.0348)	(0.0161)	(0.0424)	(0.0283)	(0.0231)	(0.0360)
(%) skilled workers	0.0123***	0.00265	0.0103***	0.0132***	0.0143***	0.0122***	0.00388	0.0105***	0.0136***	0.0147***	0.0123***	0.00277	0.0102***	0.0136***	0.0144***
	(0.00122)	(0.00355)	(0.00233)	(0.00182)	(0.00291)	(0.00123)	(0.00357)	(0.00232)	(0.00182)	(0.00293)	(0.00123)	(0.00373)	(0.00234)	(0.00183)	(0.00301)
Tech.innovation (yes=1)	0.311***	0.349***	0.407***	0.701**	#	0.310***	0.376***	0.408***	0.699**	#	0.309***	0.336**	0.409***	0.677**	#
	(0.0871)	(0.125)	(0.151)	(0.340)		(0.0886)	(0.133)	(0.151)	(0.343)		(0.0886)	(0.132)	(0.151)	(0.342)	
Exporter (yes=1)	0.287***	0.458**	0.384***	0.205***	0.181	0.288***	0.507**	0.385***	0.211***	0.181	0.291***	0.521**	0.387***	0.214***	0.177
	(0.0453)	(0.211)	(0.0812)	(0.0691)	(0.118)	(0.0454)	(0.228)	(0.0817)	(0.0699)	(0.119)	(0.0454)	(0.220)	(0.0814)	(0.0703)	(0.120)
Energy efficiency	0.00000537	0.00490***	0.000118	0.000976***	0.000381***	0.0000103	0.00656***	0.000112	0.00125***	0.000372***	0.00000413	0.00551***	0.000126	0.00116**	0.000648+
	(0.00000802)	(0.000999)	(0.0000886)	(0.000319)	(0.0000560)	(0.0000155)	(0.00191)	(0.000157)	(0.000408)	(0.0000455)	(0.00000854)	(0.00133)	(0.000102)	(0.000481)	(0.000409)
Firm size	0.210***					0.208***					0.209***				
	(0.0255)					(0.0257)					(0.0257)				
Constant	6.743***	5.565***	6.762***	9.298***	7.218***	8.465***	7.583***	7.875***	7.871***	7.427***	6.618***	7.647***	8.220***	9.465***	7.570***
	(0.445)	(0.954)	(0.276)	(0.424)	(0.488)	(1.372)	(0.430)	(0.567)	(0.876)	(0.410)	(0.618)	(0.457)	(0.320)	(0.420)	(0.429)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2000	330	814	636	220	1986	325	809	634	218	1982	325	807	632	218
R^2	0.463	0.535	0.402	0.519	0.659	0.460	0.504	0.401	0.514	0.658	0.461	0.502	0.401	0.511	0.646

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.
means perfect collinearity (in fact, all firms declare to have all the listed technological items)

Table 2: POLS estimates of labor productivity and energy efficiency by industry

(ln) Labor Productivity	*(1)* *Food prod.*	*(2)* *Textiles & App.*	*(3)* *Wood & Paper*	*(4)* *Chemicals & Min.*	*(5)* *Basic Metals*	*(6)* *Machinery*	*(7)* *Other Manuf.*
(ln) K intensity	0.294***	0.234***	0.264***	0.254***	0.237***	0.0565	0.306**
	(0.0382)	(0.0398)	(0.0673)	(0.0290)	(0.0360)	(0.0603)	(0.151)
(%) skilled workers	0.0160***	0.00812**	0.0147***	0.0109***	0.0106***	0.0113**	-0.00452
	(0.00329)	(0.00406)	(0.00394)	(0.00244)	(0.00277)	(0.00467)	(0.00963)
Tech.innovation (yes=1)	0.219*	0.239	0.0728	0.368	-0.156	#	-0.0383
	(0.130)	(0.235)	(0.440)	(0.329)	(0.314)		(0.315)
Exporter (yes=1)	0.352***	0.278**	0.350**	0.202**	0.351**	0.320	0.0326
	(0.104)	(0.119)	(0.157)	(0.0938)	(0.145)	(0.244)	(0.329)
Energy efficiency (+)	-0.000000523	0.00217***	-0.000321	0.00103*	0.000181***	-0.0000300	0.00279*
	(0.00000408)	(0.000727)	(0.00163)	(0.000572)	(0.0000552)	(0.0000756)	(0.00145)
Firm size	0.152**	0.138**	0.246**	0.211***	0.360***	0.363***	0.224
	(0.0617)	(0.0602)	(0.107)	(0.0526)	(0.0624)	(0.112)	(0.171)
Constant	5.796***	6.864***	8.809***	8.511***	7.066***	8.365***	9.016***
	(0.370)	(0.384)	(0.754)	(0.596)	(0.491)	(0.685)	(1.383)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	524	338	146	455	291	99	89
R^2	0.496	0.502	0.655	0.516	0.588	0.608	0.633

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.
*(+)*Energy efficiency= 1/[annual energy expenditure/ total annual cost of variable inputs])
means perfect collinearity (in fact, all firms declare to have all the listed technological items)

to international business literature, the positive association between exporting and virtuous management practices, such as those induced by the learning by supplying paradigm, could imply lower energy intensity. On the other hand, energy saving practices can hamper international competitiveness and negatively affect the ability to produce goods destined for exports.

We test the relationship between energy efficiency and exporting in two ways: a first workable test is to interact the variable of energy intensity with the exporter status of our sample of firms in equation 1; a second test involves looking explicitly at the direct relationship between energy efficiency and firms' exporting status (direct exporters vs non-exporters). In the latter case, using a probit specification we are also able to capture possible non-linearities in the direct relationship between the two variables of interest.

Table 3 presents the results of our first empirical test. These outcomes show that net of the usual controls, while being exporters and energy savers is alternatively positively associated, on average and *ceteris paribus*, with firm productivity, energy efficiency has a lower impact on productivity in exporting firms than non-exporting ones. This outcome is consistent for all the adopted energy intensity measures. However, it is sensitive to firm heterogeneity: it is not statistically significant for all firm categories.

To provide additional insight into the issue, Table 4 presents the same estimates by industry. Once again, we present only the more conservative estimates with the cost share measure of energy intensity. The estimates with the other measures of energy efficiency are consistent and available in the supplementary material. Table 4 confirms mixed results in the interaction between energy efficiency and exporter status. This interaction is not significant in most cases and "Food Products" and "Textiles and Apparels", while

Table 3: POLS estimates of labor productivity, energy efficiency and exporter status by firms

Dependent Variable:	**1/[annual energy expenditure/ total annual sales]**					**1/[annual energy expenditure/ total annualcost of variable inputs]**					**1/[annual energy expenditure/ total annualcost of variable inputs]**				
(ln) Labor Productivity	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*
	All Firms	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*
(ln) K intensity	0.247***	0.178***	0.188***	0.301***	0.280***	0.247***	0.179***	0.188***	0.301***	0.282***	0.246***	0.175***	0.188***	0.302***	0.271***
	(0.0160)	(0.0398)	(0.0281)	(0.0229)	(0.0346)	(0.0161)	(0.0409)	(0.0283)	(0.0232)	(0.0349)	(0.0161)	(0.0426)	(0.0284)	(0.0231)	(0.0360)
(%) skilled workers	0.0118***	0.00268	0.0100***	0.0132***	0.0146***	0.0119***	0.00378	0.0103***	0.0141***	0.0149***	0.0119***	0.00261	0.00999***	0.0136***	0.0143***
	(0.00122)	(0.00355)	(0.00233)	(0.00181)	(0.00302)	(0.00123)	(0.00359)	(0.00232)	(0.00180)	(0.00302)	(0.00122)	(0.00379)	(0.00235)	(0.00183)	(0.00303)
Tech.innovation (yes=1)	0.315***	0.348***	0.409***	0.696**	#	0.312***	0.377***	0.411***	0.682**	0	0.313***	0.338**	0.410***	0.676**	#
	(0.0869)	(0.125)	(0.152)	(0.340)		(0.0885)	(0.133)	(0.151)	(0.344)	(0)	(0.0886)	(0.132)	(0.152)	(0.342)	
Exporter (yes=1)	0.714***	0.312	1.081***	0.121	0.102	0.561***	0.806*	0.851***	-0.256	0.129	0.625***	0.832**	0.704***	0.199	0.184
	(0.124)	(0.490)	(0.220)	(0.249)	(0.187)	(0.138)	(0.474)	(0.312)	(0.268)	(0.196)	(0.106)	(0.383)	(0.228)	(0.164)	(0.210)
Energy efficiency	-0.00000121	0.00498***	0.0000648	0.00104***	0.000389***	0.00000243	0.00631***	0.0000509	0.00166***	0.000375***	-0.00000388	0.00523***	0.0000920	0.00118**	0.000640
	(0.00000684)	(0.00117)	(0.0000929)	(0.000379)	(0.0000615)	(0.0000144)	(0.00212)	(0.000162)	(0.000544)	(0.0000470)	(0.00000722)	(0.00146)	(0.000104)	(0.000547)	(0.000422)
Energy efficiency*exporter	-0.471***	0.153	-0.743***	0.0916	0.0945	-0.297**	-0.317	-0.498	0.495*	0.0613	-0.377***	-0.349	-0.350	0.0169	-0.00841
	(0.124)	(0.484)	(0.227)	(0.251)	(0.183)	(0.138)	(0.467)	(0.318)	(0.270)	(0.193)	(0.107)	(0.380)	(0.238)	(0.167)	(0.208)
Firm size	0.210***					0.208***					0.211***				
	(0.0254)					(0.0256)					(0.0256)				
Constant	6.735***	5.559***	6.813***	9.279***	7.208***	7.284***	7.608***	7.865***	7.863***	6.600***	6.611***	7.680***	8.232***	9.461***	7.571***
	(0.444)	(0.956)	(0.276)	(0.431)	(0.487)	(0.632)	(0.442)	(0.574)	(0.883)	(0.710)	(0.616)	(0.465)	(0.321)	(0.425)	(0.432)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2000	330	814	636	220	1986	325	809	634	218	1982	325	807	632	218
R^2	0.467	0.535	0.408	0.520	0.660	0.462	0.530	0.405	0.526	0.661	0.464	0.503	0.403	0.511	0.646

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.
means perfect collinearity (in fact, all firms declare to have all the listed technological items)

Table 4: POLS estimates of labor productivity, energy efficiency and exporter status by industry

Dependent Variable: (ln) Labor Productivity	*(1)* *Food prod.*	*(2)* *Textiles & App.*	*(3)* *Wood & Paper*	*(4)* *Chemicals & Min.*	*(5)* *Basic Metals*	*(6)* *Machinery*	*(7)* *Other Manuf.*
(ln) K intensity	0.291***	0.231***	0.264***	0.254***	0.233***	0.0680	0.303*
	(0.0383)	(0.0394)	(0.0673)	(0.0291)	(0.0363)	(0.0592)	(0.153)
(%) skilled workers	0.0154***	0.00835**	0.0147***	0.0107***	0.0108***	0.0111**	-0.00604
	(0.00319)	(0.00400)	(0.00394)	(0.00244)	(0.00274)	(0.00462)	(0.00947)
Tech.innovation (yes=1)	0.220*	0.226	0.0728	0.376	-0.163	#	-0.0118
	(0.129)	(0.235)	(0.440)	(0.330)	(0.321)		(0.333)
Exporter (yes=1)	1.049***	-0.289	0.350**	0.322	-0.117	0.636*	0.364
	(0.253)	(0.242)	(0.157)	(0.201)	(0.435)	(0.349)	(0.822)
Energy efficiency (+)	-0.0000134**	0.00278***	-0.000321	0.000891	0.000188***	-0.0000809	0.00240
	(0.00000570)	(0.000811)	(0.00163)	(0.000627)	(0.0000565)	(0.0000709)	(0.00177)
Energy efficiency*exporter	-0.789***	0.611***	0	-0.138	0.504	-0.454	-0.365
	(0.255)	(0.235)	(0)	(0.204)	(0.445)	(0.338)	(0.904)
Firm size	0.165***	0.137**	0.246**	0.210***	0.365***	0.396***	0.222
	(0.0612)	(0.0601)	(0.107)	(0.0528)	(0.0626)	(0.107)	(0.174)
Constant	5.809***	6.897***	8.809***	8.514***	7.057***	8.176***	9.047***
	(0.370)	(0.381)	(0.754)	(0.601)	(0.491)	(0.688)	(1.413)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	524	338	146	455	291	99	89
R^2	0.507	0.507	0.655	0.517	0.591	0.619	0.634

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.
(+) Energy efficiency= 1/[annual energy expenditure/ total annual cost of variable inputs])
means perfect collinearity (all firms declare to have all the listed technological items)

significant, present opposite signs: in practice, energy saving practices are seen to have higher impacts on the productivity of exporting firms in "Textiles and Apparels" compared to non-exporting ones, but lower impacts for their counterparts in "Food Products" compared with non-exporting ones.

These mixed results call for further investigations. We thus provide a second empirical test to directly assess the relationship between the export status of our sample of firms and their degree of energy efficiency. Note that this is a completely different exercise compared with the previous one. It looks at the presence of a direct correlation between energy saving practices and exporting, whereas the previous one looked at the relative relationship between energy efficiency and productivity between exporting and non-exporting firms. Table 5 shows the probit estimates of the above relationship by controlling for labor productivity and the usual set of exporting correlates (foreign ownership, skilled workers, technological innovation and firm size) as well as for country, province and industry dummies.[8] This additional empirical exercise also allows us to test for possible non-linearities in the relation between energy efficiency and export performance. As before, we first present this additional empirical test by firm categories: we thus find a strong positive correlation between energy efficiency and exporting only for the category of large firms. Table 6 presents this additional empirical test also by industry. In this case, the correlation between energy efficiency and exporting is significant only for "Chemicals and Mining"[9].

[8]In this specification, we use labor productivity as a control instead of its main determinants. We are thus able to increase the number of observations to over 4,700. This helps to control for possible multicollinearity across our variables. As a result, VIF statistics are close to one for all covariates.

[9]This results is not confirmed when we adopt alternative measures of energy efficiency. See the additional tables reported

Table 5: Probit estimates of energy efficiency and exporter status by firms

Dependent Variable:	**1/[annual energy expenditure/ total annual sales]**					**1/[annual energy expenditure/ total annualcost of variable inputs]**					**1/[annual energy expenditure/ total annualcost of variable inputs]**				
Exporter (yes=1)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*
	All Firms	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*
Energy efficiency	0.0000320	0.000537	0.0000761	-0.000225	0.0000407***	0.0000520	0.00140	0.000208	-0.000257	0.0000609**	0.000109	0.000333	0.000111	-0.000355	0.0000852***
	(0.0000848)	(0.000777)	(0.0000947)	(0.000228)	(0.0000132)	(0.000125)	(0.00133)	(0.000128)	(0.000328)	(0.0000257)	(0.000120)	(0.00121)	(0.000127)	(0.000396)	(0.0000268)
Foreign owned (yes=1)	0.466***	0.776**	0.661***	0.537***	0.348**	0.440***	0.700**	0.630***	0.518***	0.350**	0.438***	0.680**	0.628***	0.509***	0.355**
	(0.0685)	(0.329)	(0.143)	(0.102)	(0.150)	(0.0691)	(0.339)	(0.144)	(0.103)	(0.151)	(0.0692)	(0.340)	(0.144)	(0.103)	(0.152)
(ln) Labor Productivity	0.226***	0.226**	0.294***	0.254***	0.221***	0.235***	0.252***	0.304***	0.251***	0.220***	0.238***	0.270***	0.311***	0.253***	0.224***
	(0.0262)	(0.0894)	(0.0462)	(0.0454)	(0.0757)	(0.0264)	(0.0919)	(0.0467)	(0.0453)	(0.0758)	(0.0264)	(0.0911)	(0.0470)	(0.0458)	(0.0761)
(%) skilled workers	0.00446***	0.0138***	0.00838***	0.000659	0.000484	0.00413***	0.0108***	0.00838***	0.000872	0.000321	0.00402***	0.0111***	0.00825***	0.00102	0.000189
	(0.00141)	(0.00413)	(0.00256)	(0.00236)	(0.00345)	(0.00141)	(0.00416)	(0.00257)	(0.00236)	(0.00345)	(0.00142)	(0.00413)	(0.00258)	(0.00238)	(0.00346)
Tech.innovation (yes=1)	0.691***	0.648**	0.794***	0.295	#	0.687***	0.566**	0.793***	0.303	#	0.689***	0.558**	0.783***	0.317	#
	(0.143)	(0.266)	(0.245)	(0.484)		(0.144)	(0.263)	(0.245)	(0.487)		(0.144)	(0.261)	(0.246)	(0.487)	
Firm size	0.430***					0.432***					0.436***				
	(0.0290)					(0.0292)					(0.0292)				
Constant	-5.382***	2.392	-4.790***	1.714	-8.254***	-5.470***	-3.480***	-4.642***	1.746	-8.189	-5.543***	1.993	-4.870***	-3.296***	-2.000*
	(0.600)	.	(0.717)	.	(1.585)	(0.602)	(1.186)	(1.032)	.	(0)	(0.847)	.	(0.737)	(0.922)	(1.100)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4743	621	1900	1338	443	4689	584	1880	1325	440	4675	584	1877	1317	438
PseudoR^2	0.182	0.087	0.119	0.131	0.095	0.182	0.078	0.120	0.129	0.093	0.183	0.075	0.121	0.127	0.096

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.
means perfect collinearity (in fact, all firms declare to have all the listed technological items)

To summarize, we got mixed results on the energy efficiency-trade nexus for the LAC region: the interaction between energy efficiency and exporting is significant, on average, but both sign and significance are heterogeneous by firm size and industry, whereas signs of a significant direct relationship between energy efficiency and exporting are present only for large firms and for specific sectors.

Table 6: Probit estimates of energy efficiency and exporter status by industry

Dependent Variable: Exporter (yes=1)	(1) *Food prod.*	(2) *Textiles & App.*	(3) *Wood & Paper*	(4) *Chemicals & Min.*	(5) *Basic Metals*	(6) *Machinery*	(7) *Other Manuf.*
Energy efficiency (+)	0.0000208	0.000253	0.00253	0.000831*	-0.000203	0.000555	-0.00452
	(0.0000180)	(0.000517)	(0.00216)	(0.000454)	(0.000316)	(0.000568)	(0.00361)
Foreign owned (yes=1)	0.338**	0.853***	0.969***	0.369***	0.729***	0.352	12.05
	(0.143)	(0.223)	(0.340)	(0.134)	(0.209)	(0.393)	.
(ln) Labor Productivity	0.342***	0.188***	0.466***	0.169***	0.277***	0.424***	0.531***
	(0.0555)	(0.0667)	(0.136)	(0.0580)	(0.0819)	(0.138)	(0.156)
(%) Human K	0.00617	0.0136***	0.00239	0.00373	0.00531	-0.00349	0.0119
	(0.00385)	(0.00445)	(0.00586)	(0.00269)	(0.00380)	(0.00572)	(0.0135)
Tech.innovation (yes=1)	0.638***	0.621	0.297	#	#	#	#
	(0.217)	(0.406)	(0.459)				
Firm size	0.467***	0.564***	0.318**	0.462***	0.529***	0.199	0.500**
	(0.0669)	(0.0698)	(0.125)	(0.0606)	(0.0915)	(0.133)	(0.199)
Constant	-6.551***	-6.629***	-5.923***	-4.080***	-4.455***	-4.982***	-6.130***
	(1.138)	(1.151)	(1.533)	(0.891)	(1.030)	(1.776)	(1.806)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1064	811	248	973	559	214	169
PseudoR^2	0.273	0.284	0.236	0.181	0.265	0.174	0.349

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.
(+) Energy efficiency= 1/[annual energy expenditure/ total annual cost of variable inputs])
means perfect collinearity (all firms declare to have all the listed technological items)

5. Conclusions

This work provides empirical evidence aimed at fostering our knowledge of LAC region performances in terms of energy intensities and its links with productivity and exporting. Notwithstanding the relevance of the debate regarding the environmental impact of energy saving practices on both productivity and exporting, convincing empirical evidence has not been yet provided. To the best of our knowledge, this analysis is among one of the few firm-level empirical investigations into the correlates between energy intensity, labor productivity and exporting in the LAC region. This is highly relevant since energy saving practices, productivity and openness are all phenomena characterized by strong industrial and firm heterogeneity.

Using a pool of firm level data from the national representative World bank Enterprise Survey (WBES) dataset for thirty LAC countries and nine manufacturing industries, we find heterogeneous results by firm size and industrial sector both in the relationship between energy efficiency and productivity and between energy efficiency and exporting. Although the difficulty in determining a causal linkage between these phenomena,

in the supplementary material.

our empirical evidence that cross-industries and cross-firms differences in energy efficiency are correlated with differences in productivity works in favor of the so-called "Porter Hypothesis" that stringent environmental regulations aimed at increasing energy efficiency may lead to an improvement in productivity. However, this general statement is mitigated by strong heterogeneity by firm size and industrial sector.

This has significant policy implications. On the one hand, it suggests a review of the priorities set in current energy saving policies. First of all, the presence of non-energy benefit in terms of productivity gains should be considered in the overall assessment of the policies aimed at fostering energy efficiency. On the other hand, there is a lack of a one-size-fits-all solution because of the presence of strong heterogeneity by industries and firms. Finally, the fact that lower energy consumption does not correlate, on average, with the export status of the investigated firms excludes the possibility that stringent environmental regulations are at odds with trade liberalization policies.

References

Aiyar S. and Dalgaard C.J. (2009) Accounting for productivity: Is it ok to assume that the world is cobb–douglas?, *Journal of Macroeconomics*, 31, 2, 290–303.

Alcacer J. and Oxley J. (2014) Learning by supplying, *Strategic Management Journal*, 35, 2, 204–223.

Antweiler W., Copeland B.R. and Taylor M.S. (2001) Is free trade good for the environment?, *American Economic Review*, 91, 4, 877–908.

Benavente J. and Bravo C. (2009) Innovation, R&D Investment and productivity in Latin American and Caribbean Firms: the Chilean Case, *Documento inédito. Washington, DC: Red de Centros de Investigación de América Latina y el Caribe, Banco Interamericano de Desarrollo*.

Benavente M.J. (2006) The role of research and innovation in promoting productivity in Chile, *Economics of Innovation and New Technology*, 15, 4-5, 301–315.

Bernard A.B., Jensen J.B., Redding S.J. and Schott P.K. (2007) Firms in international trade, *The Journal of Economic Perspectives*, 21, 3, 105–130.

Bloom N., Genakos C., Martin R. and Sadun R. (2010) Modern management: good for the environment or just hot air?, *The Economic Journal*, 120, 544, 551–572.

Boyd G.A. and McClelland J.D. (1999) The impact of environmental constraints on productivity improvement in integrated paper plants, *Journal of environmental economics and management*, 38, 2, 121–142.

Boyd G.A. and Pang J.X. (2000) Estimating the linkage between energy efficiency and productivity, *Energy policy*, 28, 5, 289–296.

Boyd G.A., Tolley G. and Pang J. (2002) Plant level productivity, efficiency, and environmental performance of the container glass industry, *Environmental and Resource Economics*, 23, 1, 29–43.

Brännlund R. and Lundgren T. (2010) Environmental policy and profitability: evidence from Swedish industry, *Environmental Economics and Policy Studies*, 12, 1-2, 59–78.

Brännlund R., Lundgren T. *et al.* (2009) Environmental policy without costs? A review of the Porter hypothesis, *International Review of Environmental and Resource Economics*, 3, 2, 75–117.

Brunnermeier S.B. and Levinson A. (2004) Examining the evidence on environmental regulations and industry location, *The Journal of Environment & Development*, 13, 1, 6–41.

Bustos P. (2011) Trade liberalization, exports, and technology upgrading: Evidence on the impact of MERCOSUR on Argentinian firms, *The American economic review*, 101, 1, 304–340.

Chudnovsky D., López A. and Pupato G. (2006) Innovation and productivity in developing countries: A study of Argentine manufacturing firms' behavior (1992–2001), *Research policy*, 35, 2, 266–288.

Cole M.A. and Elliott R.J. (2003) Determining the trade–environment composition effect: the role of capital, labor and environmental regulations, *Journal of Environmental Economics and Management*, 46, 3, 363–383.

Cole M.A., Elliott R.J. and Shimamoto K. (2006) Globalization, firm-level characteristics and environmental management: A study of Japan, *Ecological Economics*, 59, 3, 312–323.

Crespi G., Tacsir E. and Vargas F. (2016) Innovation dynamics and productivity: Evidence for Latin America, in: *Firm Innovation and Productivity in Latin America and the Caribbean*, Springer, 37–71.

Dowell G., Hart S. and Yeung B. (2000) Do corporate global environmental standards create or destroy market value?, *Management science*, 46, 8, 1059–1074.

Duro J.A., Alcántara V. and Padilla E. (2010) International inequality in energy intensity levels and the role of production composition and energy efficiency: an analysis of OECD countries, *Ecological Economics*, 69, 12, 2468–2474.

Ederington J. and Minier J. (2003) Is environmental policy a secondary trade barrier? An empirical analysis, *Canadian Journal of Economics/Revue canadienne d'économique*, 36, 1, 137–154.

Eifert B., Gelb A. and Ramachandran V. (2005) *Business environment and comparative advantage in Africa: Evidence from the investment climate data*, The World Bank.

Farole T. and Winkler D. (2014) *Making foreign direct investment work for Sub-Saharan Africa: local spillovers and competitiveness in global value chains*, World Bank Publications.

Freeman S.L., Niefer M.J. and Roop J.M. (1997) Measuring industrial energy intensity: practical issues and problems, *Energy policy*, 25, 7-9, 703–714.

Galdeano-Gómez E. (2010) Exporting and environmental performance: a firm-level productivity analysis, *The World Economy*, 33, 1, 60–88.

Gray W.B. and Shadbegian R.J. (1993) Environmental regulation and manufacturing productivity at the plant level, Technical report, National Bureau of Economic Research.

Grazzi M. and Pietrobelli C. (2016) *Firm Innovation and Productivity in Latin America and the Caribbean: The Engine of Economic Development*, Springer.

Greenaway D. and Kneller R. (2007) Firm heterogeneity, exporting and foreign direct investment, *The Economic Journal*, 117, 517, F134–F161.

Grossi L. and Mussini M. (2017) Inequality in Energy Intensity in the EU-28: Evidence from a New Decomposition Method, *The Energy Journal*, 38, 4.

Guloglu B. and Tekin R.B. (2012) A panel causality analysis of the relationship among research and development, innovation, and economic growth in high-income OECD countries, *Eurasian Economic Review*, 2, 1, 32–47.

Hall R.E. and Jones C.I. (1999) Why do some countries produce so much more output per worker than others?, *The quarterly journal of economics*, 114, 1, 83–116.

Hamamoto M. (2006) Environmental regulation and the productivity of Japanese manufacturing industries, *Resource and energy economics*, 28, 4, 299–312.

Harrington W., Morgenstern R.D. and Nelson P. (2000) On the accuracy of regulatory cost estimates, *Journal of Policy Analysis and Management*, 297–322.

Heras-Saizarbitoria I., Molina-Azorín J.F. and Dick G.P. (2011) Iso 14001 certification and financial performance: selection-effect versus treatment-effect, *Journal of Cleaner Production*, 19, 1, 1–12.

International Energy Agency (2014) *Energy Efficiency Indicators: Essentials for policy making*.

Jaffe A.B., Peterson S.R., Portney P.R. and Stavins R.N. (1995) Environmental regulation and the competitiveness of US manufacturing: what does the evidence tell us?, *Journal of Economic literature*, 33, 1, 132–163.

Lean H.H. and Smyth R. (2010a) Multivariate Granger causality between electricity generation, exports, prices and GDP in Malaysia, *Energy*, 35, 9, 3640–3648.

Lean H.H. and Smyth R. (2010b) On the dynamics of aggregate output, electricity consumption and exports in Malaysia: evidence from multivariate Granger causality tests, *Applied Energy*, 87, 6, 1963–1971.

Lileeva A. and Trefler D. (2010) Improved access to foreign markets raises plant-level productivity...for some plants, *The Quarterly Journal of Economics*, 125, 3, 1051–1099.

Majano A.M. (2014) Study on the Development of the Renewable Energy Market in Latin America and the Caribbean, Technical report, Inter-American Development Bank.

Melitz M.J. (2003) The impact of trade on intra-industry reallocations and aggregate industry productivity, *Econometrica*, 71, 6, 1695–1725.

Melitz M.J. and Redding S.J. (2014) Heterogeneous firms and trade, *Handbook of International Economics,*, 4, 1–54.

Mohr R.D. (2002) Technical change, external economies, and the Porter hypothesis, *Journal of Environmental economics and management*, 43, 1, 158–168.

Molina-Azorín J.F., Claver-Cortés E., Pereira-Moliner J. and Tarí J.J. (2009) Environmental practices and firm performance: an empirical analysis in the Spanish hotel industry, *Journal of Cleaner Production*, 17, 5, 516–524.

Montalbano P., Nenci S. and Pietrobelli C. (2017) Opening and linking up: firms, GVCs, and productivity in Latin America, *Small Business Economics*, 1–19.

Mulder P. and de Groot H.L. (2012) Structural change and convergence of energy intensity across OECD countries, 1970–2005, *Energy Economics*, 34, 6, 1910–1921.

Narayan P.K. and Smyth R. (2009) Multivariate Granger causality between electricity consumption, exports and GDP: evidence from a panel of Middle Eastern countries, *Energy Policy*, 37, 1, 229–236.

Pagés C. (2010) The importance of ideas: Innovation and productivity in Latin America, in: *The Age of Productivity*, Springer, 223–255.

Patterson M.G. (1996) What is energy efficiency?: Concepts, indicators and methodological issues, *Energy policy*, 24, 5, 377–390.

Pérez P., Dutrénit G. and Barceinas F. (2005) Actividad innovadora y desempeño económico: un análisis econométrico del caso mexicano, *Indicadores de Ciencia y Tecnología en Iberoamérica. Buenos Aires, Argentina: RICYT*.

Porter M.E. and Van der Linde C. (1995) Toward a new conception of the environment-competitiveness relationship, *The journal of economic perspectives*, 9, 4, 97–118.

Proskuryakova L. and Kovalev A. (2015) Measuring energy efficiency: Is energy intensity a good evidence base?, *Applied energy*, 138, 450–459.

Raffo J., Lhuillery S. and Miotti L. (2008) Northern and southern innovativity: a comparison across European and Latin American countries, *The European Journal of Development Research*, 20, 2, 219–239.

Rouvinen P. (2002) R&D-productivity dynamics: causality, lags, and "dry holes", *Journal of Applied Economics*, 5, 1.

Roy J. and Yasar M. (2015) Energy efficiency and exporting: Evidence from firm-level data, *Energy Economics*, 52, 127–135.

Sadorsky P. (2011) Trade and energy consumption in the Middle East, *Energy Economics*, 33, 5, 739–749.

Sadorsky P. (2012) Energy consumption, output and trade in South America, *Energy Economics*, 34, 2, 476–488.

Stein E., Crespi G. *et al.* (2014) *Rethinking Productive Development: Sound Policies and Institutions for Economic Transformation*, Springer.

Tobey J.A. (1990) The effects of domestic environmental policies on patterns of world trade: an empirical test, *Kyklos*, 43, 2, 191–209.

Tybout J.R. (2000) Manufacturing firms in developing countries: How well do they do, and why?, *Journal of Economic literature*, 38, 1, 11–44.

Verardi V., Dehon C. *et al.* (2010) Multivariate outlier detection in Stata, *The Stata Journal*, 10, 2, 259–266.

Wagner J. (2007) Exports and productivity: A survey of the evidence from firm-level data, *The World Economy*, 30, 1, 60–82.

Wagner M. (2003) *The Porter hypothesis revisited: a literature review of theoretical models and empirical tests*, Centre for Sustainability Management.

Walley N. and Whitehead B. (1994) It's not easy being green, *Reader in Business and the Environment*, 36, 81.

Worrell E., Laitner J.A., Ruth M. and Finman H. (2003) Productivity benefits of industrial energy efficiency measures, *Energy*, 28, 11, 1081–1098.

Zeng S., Meng X., Yin H., Tam C.M. and Sun L. (2010) Impact of cleaner production on business performance, *Journal of Cleaner Production*, 18, 10-11, 975–983.

Appendix A. Appendix

Table A.1: The LAC Sample: number of firms and measures of energy intensity by country (average annual values by firm). All monetary values are in 2009 U.S. dollars.

Country	**Year**	**Total Firms**	**Exporting(*)**	**Ratio of annual energy exp. (fuel and electricity)/ total annual sales (Last Fiscal Year)**	**Ratio of annual energy exp. (fuel and electricity)/ annual value added (Last Fiscal Year)**	**Ratio of annual energy exp. (fuel and electricity)/ total annual cost of variable inputs (Last Fiscal Year)**
Antigua and Barbuda	2010	30	5	0.092	0.204	0.128
Argentina	2006	375	126	0.025	0.061	0.043
	2010	508	166	0.029	0.135	0.041
Bahamas	2010	33	6	0.059	0.148	0.076
Barbados	2010	35	18	0.061	0.124	0.087
Belize	2010	69	14	0.040	0.088	0.061
Bolivia	2006	233	35	0.048	0.129	0.089
	2010	29	6	0.050	0.130	0.075
Brazil	2009	1,040	84	0.044	0.127	0.086
Chile	2006	474	70	0.039	0.119	0.062
	2010	546	102	0.054	0.486	0.085
Colombia	2006	530	64	0.030	0.064	0.052
	2010	524	113	0.039	0.102	0.058
Costa Rica	2010	185	47	0.055	0.140	0.077
Dominica	2010	24	7	0.047	0.109	0.061
Dominican Republic	2010	90	22	0.070	0.194	0.101
Ecuador	2006	260	37	0.046	0.142	0.071
	2010	95	15	0.039	0.083	0.062
El Salvador	2006	374	110	0.054	0.140	0.090
	2010	86	40	0.075	0.253	0.105
Grenada	2010	18	4	0.088	0.197	0.119
Guatemala	2006	274	70	0.063	0.230	0.110
	2010	193	58	0.085	0.351	0.121
Guyana	2010	56	16	0.096	0.262	0.139
Honduras	2006	219	33	0.082	0.243	0.131
	2010	75	10	0.068	1.048	0.123
Jamaica	2010	85	16	0.042	0.105	0.058
Mexico	2006	873	86	0.034	0.067	0.067
	2010	960	170	0.059	0.153	0.088
Nicaragua	2006	256	27	0.084	0.702	0.138
	2010	70	9	0.089	0.269	0.150
Panama	2006	142	17	0.058	0.126	0.121
	2010	36	1	0.083	0.389	0.159
Paraguay	2006	145	22	0.060	0.164	0.098
	2010	83	19	0.056	0.129	0.089
Peru	2006	258	66	0.050	0.177	0.086
	2010	494	152	0.051	0.180	0.076
St. Kitts & Nevis	2010	20	7	0.056	0.118	0.066
Saint Lucia	2010	59	18	0.100	0.268	0.120
St. Vincent & the Grenadines	2010	41	12	0.104	0.212	0.153
Suriname	2010	70	10	0.110	0.257	0.135
Trinidad and Tobago	2010	94	30	0.053	0.107	0.076
Uruguay	2006	183	44	0.051	0.129	0.078
	2010	190	45	0.050	0.138	0.071
Total and average values		**10,434**	**2,029**	**0.050**	**0.178**	**0.081**

Table A.2: The LAC Sample: number of firms and measures of energy intensity by industry (average annual values by firm). All monetary values are in 2009 U.S. dollars.

ISIC activity	**Total Firms**	**Exporting(*)**	**Ratio of annual energy exp. (fuel and electricity)/ total annual sales (Last Fiscal Year)**	**Ratio of annual energy exp. (fuel and electricity)/ annual value added (Last Fiscal Year)**	**Ratio of annual energy exp. (fuel and electricity)/ total annual cost of variable inputs (Last Fiscal Year)**
Basic Metals	1,053	200	0.050	0.128	0.079
Chemicals & Mine	2,373	494	0.048	0.173	0.083
Electrical Equip	203	59	0.032	0.224	0.056
Food Products	2,442	439	0.063	0.278	0.101
Machinery	643	149	0.032	0.070	0.057
Other Manufactur	498	68	0.055	0.159	0.088
Textiles & Appar	2,585	509	0.043	0.127	0.069
Transport Equipm	143	23	0.039	0.186	0.064
Wood & Paper	494	88	0.059	0.213	0.089
Total and average values	**10,434**	**2,029**	**0.050**	**0.178**	**0.081**

Table A.3: The LAC Sample: number of firms and measures of energy intensity by firm size (average annual values by firm). All monetary values are in 2009 U.S. dollars.

Firm size (**)	**Total Firms**	**Exporting(*)**	**Ratio of annual energy exp. (fuel and electricity)/ total annual sales (Last Fiscal Year)**	**Ratio of annual energy exp. (fuel and electricity)/ annual value added (Last Fiscal Year)**	**Ratio of annual energy exp. (fuel and electricity)/ total annual cost of variable inputs (Last Fiscal Year)**
Micro	2,404	131	0.064	0.187	0.099
Small	4,631	632	0.049	0.164	0.080
Medium	2,626	869	0.042	0.207	0.067
Large	773	397	0.045	0.131	0.080
Total and average values	**10,434**	**2,029**	**0.050**	**0.178**	**0.081**

Table A.4: POLS estimates of labor productivity controlling for R&D expenses

Dependent Variable:	**1/[annual energy expenditure/ total annual sales]**					**1/[annual energy expenditure/ total annual value added]**					**1/[annual energy expenditure/ total annualcost of variable inputs]**				
(ln) Labor Productivity	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*
	All Firms	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*	*All Firms*	*Micro Firms*	*Small Firms*	*Medium Firms*	*Large Firms*
(ln) K intensity	0.225***	0.153	0.149***	0.308***	0.228***	0.225***	0.188*	0.141***	0.304***	0.229***	0.221***	0.188+	0.141***	0.306***	0.217***
	(0.0257)	(0.118)	(0.0430)	(0.0315)	(0.0470)	(0.0247)	(0.112)	(0.0422)	(0.0302)	(0.0462)	(0.0250)	(0.122)	(0.0423)	(0.0305)	(0.0480)
(%) skilled workers	0.0134***	0.00278	0.0113***	0.0128***	0.0129***	0.0120***	-0.00102	0.00835**	0.0134***	0.0125***	0.0120***	-0.00254	0.00805**	0.0137***	0.0120***
	(0.00160)	(0.00705)	(0.00372)	(0.00229)	(0.00451)	(0.00155)	(0.00664)	(0.00332)	(0.00221)	(0.00380)	(0.00155)	(0.00695)	(0.00335)	(0.00216)	(0.00381)
(ln) R&D	0.110***	0.0493	0.132***	0.0901***	0.123**	0.108***	0.0782	0.117***	0.101***	0.121**	0.108***	0.0538	0.115***	0.0905***	0.121**
	(0.0201)	(0.107)	(0.0415)	(0.0341)	(0.0555)	(0.0197)	(0.0954)	(0.0411)	(0.0331)	(0.0514)	(0.0198)	(0.0943)	(0.0411)	(0.0334)	(0.0519)
Exporter (yes=1)	0.154**	0.550	0.337**	0.0364	0.201	0.169***	0.822*	0.372***	0.0577	0.145	0.177***	0.646+	0.377***	0.0668	0.140
	(0.0643)	(0.404)	(0.144)	(0.0956)	(0.166)	(0.0612)	(0.486)	(0.133)	(0.0930)	(0.153)	(0.0612)	(0.433)	(0.132)	(0.0925)	(0.156)
Energy efficiency	0.000186	0.00566***	0.0000178	0.000696***	0.000357***	0.000198	0.00587**	0.0000374	0.000893***	0.000334***	0.0000930	0.00573*	0.0000613	0.000858**	0.000623
	(0.000160)	(0.00191)	(0.0000801)	(0.000256)	(0.0000463)	(0.000150)	(0.00239)	(0.000107)	(0.000221)	(0.0000380)	(0.0000802)	(0.00289)	(0.0000748)	(0.000404)	(0.000434)
Firm size	0.0803*					0.0924**					0.0953**				
	(0.0472)					(0.0451)					(0.0453)				
Constant	6.623***	8.405***	7.361***	6.260***	8.881***	5.932***	7.813***	7.591***	6.096***	8.906***	6.675***	8.290***	7.959***	6.193***	9.037***
	(0.344)	(1.405)	(0.861)	(0.413)	(0.812)	(0.443)	(1.321)	(0.848)	(0.405)	(0.741)	(0.340)	(1.376)	(0.610)	(0.405)	(0.752)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	846	100	310	311	125	915	108	341	328	138	913	108	340	327	138
R^2	0.514	0.658	0.487	0.634	0.738	0.503	0.630	0.454	0.626	0.720	0.501	0.612	0.454	0.628	0.704

Notes: * Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk means the coefficient is not different from zero with statistical significance. Robust standard errors in parentheses.